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Furunculosis in Kelts

By ISABEL W. SMITH, B.Sc., Ph.D.

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By ISABEL W. SMITH, B.Sc., Ph.D.
Marine Laboratory, Aberdeen

EDINBURGH: HER MAJESTY'S STATIONERY OFFICE
1962

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Furunculosis in Kelts

INTRODUCTION

Furunculosis, which is a well-known disease of salmonids, is caused by *Bacillus salmonicida*. It has been recognised for over 50 years as a cause of death during the summer, especially when the rivers run low and the water temperature rises to 55°F. There have, however, been few records of the occurrence of the disease among spent salmon although Hofer (1906, p. 4) mentioned that furunculosis often attacked trout at spawning time and Economon (1960) has reported the disease in spent northern pike (*Esox lucius*). Rushton (1933a) and Slack (1937) have also reported that trout succumbed to the disease in the autumn in the rivers of southern England.

In the Second Interim Report of the Furunculosis Committee (1933), Adamson and Buxton state (p. 14) that an outbreak of furunculosis occurred among kelts in both the North Esk and the Deveron during the winter of 1931-32 and they add that the weather was 'exceptionally mild for the period of the year.' In one of these rivers, where the spawning stock was larger than usual and four times as many dead fish were removed, they note that 'the mortality among the male kelts was only from two to three times that of the previous years, while from five to seven times the number of female kelts died (few of which usually succumb).' Adamson and Buxton (1935), after referring to the 1931-32 outbreak, add (p. 13) 'This feature was not, so far as we are aware, repeated in the winter of 1933-34.' Adamson and Buxton (1933) did not give any indication of the numbers of fish dying but Menzies (1932) stated that 'In one district something like 1,500 dead salmon were picked up, almost all of which, from the samples they received, had died from furunculosis. It was the kelt salmon which were affected, and the majority were males.' Rushton (1933a), when considering the mortality due to furunculosis in the spring of 1933, stated that 'This year relatively higher temperatures have been accompanied with a somewhat increased mortality in males.'

Smith (1960) reported a high incidence of furunculosis in kelts in some Scottish rivers in the winter of 1958-59 and a lower incidence in 1959-60. This survey has been continued and extended and this paper summarises the results obtained.

INCIDENCE OF THE DISEASE

As can be seen from Table 1, which gives the results of the examination of kelts from 1929 until the beginning of this survey, very few kelts have been examined for the presence of furunculosis during this period. Of the 79 fish examined, 31 were infected with furunculosis, the rivers concerned being the Aberdeenshire Dee, North Esk, South Esk, Forss and Deveron. Table 2 shows the results of the examinations carried out on dead salmon and sea trout kelts during the last three winters. In 1958-59, 88 from a total of 125 fish were infected. These kelts came from eight river systems, five of which (the Aberdeenshire Dee, North Esk, South Esk, Tweed and Conon) were shown to have infected kelts. The climatic conditions of the autumn of 1958 were such that the rivers were very low. This meant that the dead fish could easily be observed and removed and also that the fish would be confined in the deeper pools; a factor which would, no doubt, influence the spread of the disease. In order to discover if this outbreak of furunculosis was an isolated happening, possibly aggravated by the low water level, it was decided to continue the survey in subsequent years. Unfortunately the autumn of 1959 proved to be very wet, thus producing spate conditions in most of the rivers. However, 27 kelts from six rivers were sent for examination. Of these, 9, from four rivers (the Aberdeenshire Dee, North Esk, Spey and Deveron) were infected with furunculosis. This apparent difference in the incidence of furunculosis in the two years made it essential that the survey be continued in 1960-61 when it was hoped the weather conditions would be more favourable for the collection of fish. Fortunately, although there was more water than in 1958-59, it was possible to remove kelts and the results showed that of the 134 specimens examined 91 were infected with furunculosis. The kelts came from ten river systems, eight of which (the Aberdeenshire Dee, Bervie, North Esk, South Esk, Tweed, Shin, Conon and Deveron) were found to have infected fish.

TABLE 1

RESULTS OF THE EXAMINATION OF KELTS, 1929-58

Year	Source	No. of Kelts					
		Male		Female		Sex unknown	
		Fur.	Neg.	Fur.	Neg.	Fur.	Neg.
1929	Bag nets					0	12
1930	River Tay					0	1
	River Tweed					0	10
1931	River North Esk	0	1	1	0		
	River South Esk					0	1
	River Forss	1	0	0	0		
	River Deveron	1	0	0	0		
	Sea	0	1	0	0		
1932	River North Esk	11	3	6	2		
	River South Esk	0	0	1	1		
	River Tweed	0	0	0	1		
	River Deveron	4	0	0	0		
1933	River North Esk					2	0
	River South Esk					1	0
1938	River North Esk	0	1	2	4		
	River Deveron	0	1	0	0		
1955	River Dee (Aberdeenshire)	0	0	0	3		
1957	River Dee (Aberdeenshire)	0	0	0	2		
	River Spey	0	1	0	0		
1958 (to Nov.)							
	River Dee (Aberdeenshire)	0	0	1	2		
	River Doon	0	1	0	0		
		17	9	11	15	3	24

Fur.—furunculosis present Neg.—result of test negative

TABLE 2

RESULTS OF THE EXAMINATION OF KELTS FROM SCOTTISH RIVERS, 1958-61

River	1958-59				1959-60				1960-61			
	Male		Female		Male		Female		Male		Female	
	Fur.	Neg.	Fur.	Neg.	Fur.	Neg.	Fur.	Neg.	Fur.	Neg.	Fur.	Neg.
Dee (Aberdeenshire)	54	10	7	5	4	7	0	3	37	10	3	1
Bervie	0	3	0	0	0	0	0	0	0	2	1	0
North Esk	11	7	1	0	1	0	0	0	15	3	3	3
South Esk	12	4	0	3	0	0	0	0	4	4	0	0
Tay	0	0	0	0	0	0	0	0	0	1	0	0
Tweed	1	2	0	1	0	0	0	0	1	0	0	0
Doon	0	1	0	0	0	0	0	0	0	0	0	0
Shin	0	0	0	0	0	0	0	0	3	0	0	0
Conon	1	0	1	0	0	2	0	2	2	1	1	0
Spey	0	1	0	0	1	1	0	2	0	13	0	1
Deveron	0	0	0	0	3	0	0	0	20	4	1	0
Ythan	0	0	0	0	0	1	0	0	0	0	0	0
	79	28	9	9	9	11	0	7	82	38	9	5

Fur.—furunculosis present Neg.—result of test negative

Arrangements were made (through the kind co-operation of Mr. F. T. K. Pentelow of the Ministry of Agriculture, Fisheries and Food) for kelts from rivers in England and Wales to be examined in 1959-60 and 1960-61. The results are given in Table 3, which shows that furunculosis occurred in kelts from all but one of the eight rivers surveyed both in 1959-60 and in 1960-61. In 1959-60, 16 of 29 specimens and in 1960-61, 45 of 68 specimens were found to be infected. Recently Hewetson (1962) has reported that the examination of 159 kelts from four Irish rivers (the Boyne, Erne, Owenea and Shannon) revealed only one case of infection with furunculosis. This would suggest that furunculosis in kelts is much less common in Ireland than it is in England, Wales or Scotland. It should be noted, however, that about three-quarters of the Irish fish came from one river (the Owenea) and that most of these were fish stripped in a hatchery, so that conditions in Ireland may not be strictly comparable with those elsewhere.

TABLE 3

RESULTS OF THE EXAMINATION OF KELTS FROM ENGLAND AND WALES

River or Area	1959-60		1960-61	
	Fur.	Neg.	Fur.	Neg.
Itchen	1	1		
Test	4	1		
Yarty			7	0
Exe			5	2
Dart			1	0
Severn			0	2
South Wales	1	2		
Towy	1	0		
Ceiwr			2	4
Clettwr	5	0	28	6
Teify	2	1	1	1
Lune	0	5		
Derwent	2	3		
Eden			1	8
	16	13	45	23

EXTERNAL SYMPTOMS

Salmon which are suffering from furunculosis show a variety of external symptoms ranging from congestion of the fins, haemorrhage at the vent and furuncles, through congestion of the fins only to the absence of any external symptoms. Table 4 shows the distribution of these symptoms in the 194 unspent fish examined during the seven year period 1954-60. It can be seen that congestion of the fins occurs frequently, sometimes alone, but more commonly in conjunction with haemorrhage at the vent, and sometimes, with furuncles. Kelts, on the other hand, do not show such a high incidence of congestion of the fins or of combined symptoms and in no case were all three symptoms present together.

When the number of unspent fish showing one or more external signs is compared with the number of kelts we find that of 194 unspent fish, 142 (73·2%) showed some external sign while only 51 (33%) of the 172 kelts with furunculosis showed external symptoms. This is shown in Fig. 1 which also shows the incidence of blemishes in the unspent fish from October to December, i.e. the period when most of the dead kelts are found. Over this period, only 43% of the unspent fish showed external symptoms, a proportion much closer to that found for kelts.

Thus the possibility of an unspent fish developing external symptoms is much greater in the summer months, though any unspent fish is more likely to develop such symptoms than a kelt. This does not agree with the observation that at higher temperatures during the summer, fish are more likely to die from an acute infection of furunculosis (in which there are no external symptoms), than from a chronic infection (where furuncles are present). It might, however, explain why the incidence of furunculosis in kelts has hitherto gone unnoticed.

SEX OF INFECTED FISH

Table 5 shows that, of all the unspent fish which had furunculosis, 59 were males and 132 were females (the sex of another eight could not be determined as they were either immature or in an advanced state of decomposition). The ratio of male to female is therefore 1:2·2. Table 2, however, shows that, among kelts, the male to female ratio was 1:0·1 which suggests that the relative susceptibility of a male salmon to furunculosis is greatly increased when it is a kelt.

It is well known that more male salmon die after spawning than females. The District Fishery Board of the Aberdeenshire Dee keep records of all the kelts which their bailiffs bury each winter and an analysis of these records for the period 1943-57 shows that, over these 15 years, males formed 91-98% of the total buried. The proportion of males buried in 1958, 1959 and 1960, when furunculosis was shown to be present, was 97%, 97% and 95% respectively so there is no reason to suspect that the sex ratio among dead kelts in these three years was at all unusual.

The only reason which has previously been given for this high death rate in male Atlantic salmon kelts is exhaustion after spawning, but the cause of this mortality has not been thoroughly investigated. Some studies have been made on Pacific salmon and migratory and non-migratory rainbow trout (Hane and Robertson, 1959; Robertson and Wexler, 1959, 1960; Robertson 1961 and Robertson *et al.* 1961). This work shows that the life span of kokanee salmon (*Oncorhynchus nerka kennerlyi*) can be increased by castration and the authors suggest that the production of the gonads (at least in the males) has more influence on the subsequent death of the fish than the actual spawning process. Pacific salmon kelts have not, however, been examined for the presence of furunculosis (Robertson, personal communication). If the susceptibility of male and female Atlantic salmon kelts to furunculosis is different this could explain why so many males die after spawning but the reason for this difference in susceptibility has still to be discovered. It seemed possible, for example, that female kelts might have an antibody in their blood which could protect them from furunculosis. Blood was, therefore, obtained by cardiac puncture from a number of newly-dead male and female kelts. After the blood had clotted at 5°C, the serum was pipetted off and sterilised by Seitz filtration. It was then titrated against a culture of *B. salmonicida* by the complement-fixation method (Blake and Anderson, 1930) and the tests were controlled by the use of an immune rabbit serum. In no instance, not even in the two early cases of furunculosis, was there any appreciable fixation of complement in the 9 male and 31 female sera tested. The females do not, therefore, appear to have any protective antibody and the reason for any difference in susceptibility is still not known.

EFFECTS OF RIVER CONDITIONS

In the outbreak of furunculosis among kelts during the winter of 1931-32, it was noted that the water temperatures in the north of Scotland were in the region of 45-50°F (Menzies 1932). Records of the water temperature of the River Dee were not available during the period of this study, but the mean monthly air temperatures published by the Meteorological Office can be used as a rough guide to the conditions obtaining during the three winters under discussion. An examination of the records for Braemar shows that the air temperatures were not unusually high during November and December 1958, 1959 or 1960 so that the high incidence of furunculosis among kelts in at least two of these years is almost certainly not linked with unusually high water temperatures.

There were, however, marked differences in the rainfall at Braemar during the autumn of these three years. In 1958 and 1960 the rainfall for November and December was less than eight inches, but the corresponding figure for 1959 was over twelve inches. The percentage infection in the River Dee during the three years 1958-60 was 84·7, 28·6 and 78·0 respectively so there would appear to be a correlation between high autumn rainfall and low incidence of furunculosis. This might arise because, in a wet autumn, dead kelts would be washed downstream more quickly and so would be less likely to infect live kelts, but this possibility requires further study.

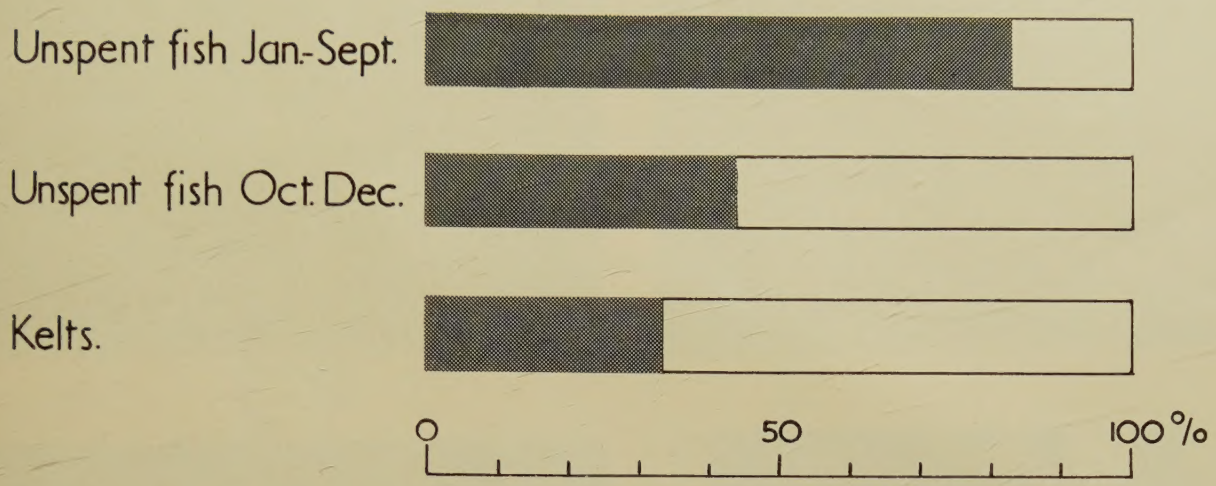
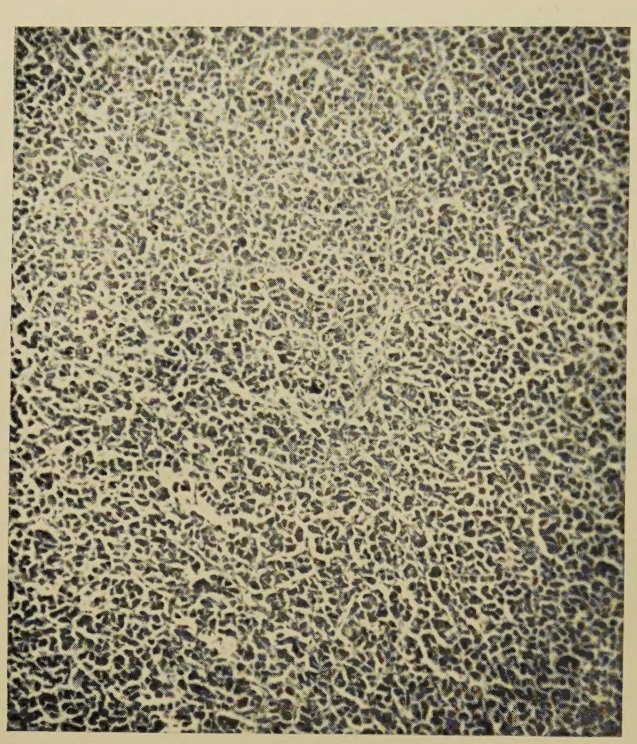


Fig. 1. The occurrence of external symptoms on fish suffering from furunculosis.



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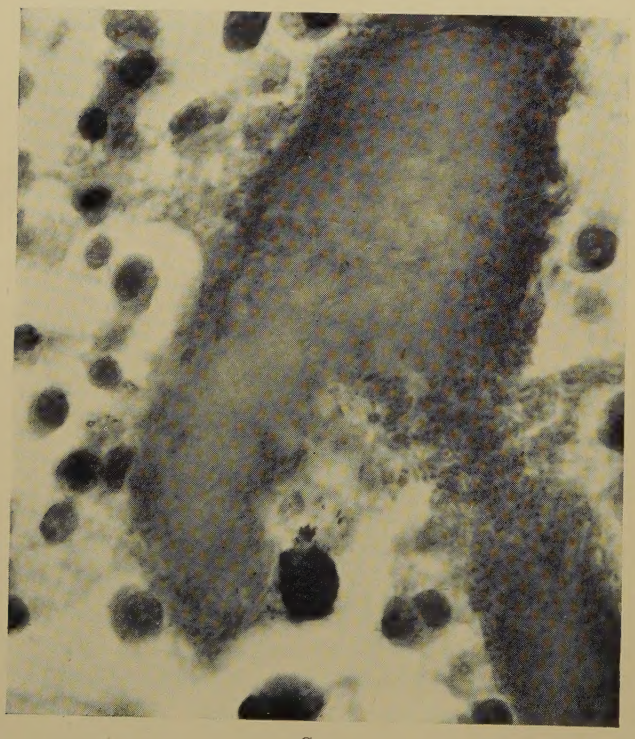

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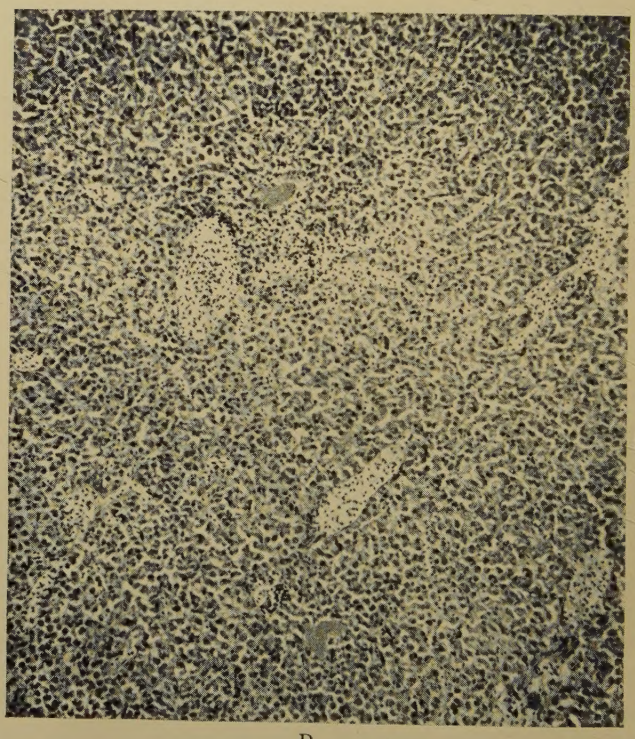

D

Fig. 2. A. Section of an uninfected salmon liver, x100 (stained Gram)
B. Section of an infected salmon liver showing densely stained micro-colonies of *B. salmonicida*, x100 (stained Gram)
C. Micro-colony of *B. salmonicida* in salmon liver, x1200 (stained Gram)
D. Micro-colonies of *B. salmonicida* in salmon liver, x100 (stained haematoxylin and eosin). The micro-colonies are less densely stained.

TABLE 4

OCCURRENCE OF EXTERNAL SYMPTOMS ON FISH SUFFERING FROM FURUNCULOSIS

Type of fish	Total no. Recorded	F.c.	V.h.	F.	F.c.+V.h.	F.c.+F.	V.h.+F.	F.c.+V.h.+F.
Unspent fish (total) .	194	21	25	24	50	3	7	11
Unspent fish (Oct-Dec)	46	9	3	7	0	0	1	0
Kelts . . .	172	4	23	19	3	0	2	0

F.c.—fins congested. V.h.—vent haemorrhagic. F.—furuncles or other external haemorrhagic blemishes.

TABLE 5

SEX OF UNSPENT SALMON, SEA TROUT AND BROWN TROUT SUFFERING FROM FURUNCULOSIS, 1954-60

River or Area	Male	Female	Sex unknown
Dee (Aberdeenshire) .	18	25	—
North Esk . . .	7	14	—
South Esk . . .	6	18	1
Tay	1	5	—
Tweed	6	8	—
Border Esk . . .	—	2	—
Annan	—	—	5
Nith	—	2	—
Luce	—	1	—
Laxford . . .	—	1	—
Hope	—	1	—
Kyle of Sutherland . .	—	3	—
Conon . . .	14	34	—
Ness	—	1	—
Nairn	—	1	—
Findhorn . . .	—	4	—
Spey	4	7	—
Deveron . . .	1	3	1
Ythan	—	1	—
Pitlochry . . .	2	1	1
	59	132	8

TABLE 6

EFFECT OF INTERVAL BETWEEN DEATH OF KELTS AND AUTOPSY

	First degree infection	Second degree infection
Short interval .	42·7%	58·3%
Long interval .	27·0%	73·0%

VARIATION IN DEGREE OF INFECTION

When the results of the bacteriological and histological examination of 189 of the unspent fish suffering from furunculosis were considered it was found that, roughly, the fish showed one of the following three degrees of infection.

(i) The organism could be isolated from the fish but there were no detectable histological changes. This means that either the infection was septicaemic or that the fish was a 'carrier' and the only way to distinguish between these two types would be by a quantitative study of the number of bacteria present (17 cases).

(ii) The organism could be isolated and micro-colonies of the pathogen were found in one or more of the internal organs (Fig. 2B, C, D) (131 cases).

(iii) The internal organs of the fish had been completely liquified by this highly proteolytic organism (41 cases).

As in all histological work, no hard and fast rules can be applied and there are numerous intermediates between these three degrees. For example, in some fish the spleen and the kidney were completely liquified but the liver was intact, though sections of the latter showed the presence of micro-colonies of *B. salmonicida.*

When the above criteria were applied to kelts it was found that, of the 171 recorded, 60 had a first degree infection, 111 a second degree infection and none a third degree infection. In the summer, if a dead fish yields *B. salmonicida* on culture, it is generally accepted that it died from furunculosis unless the numbers of the organism are so small as to place it in the carrier group and here it is usually possible to attribute death to injury. When the kelt results are considered, however, a different picture emerges. The absence of a third degree infection is not totally unexpected as, at lower temperatures, the metabolic rate of *B. salmonicida* would doubtless be reduced and there would be less likelihood of a third degree infection developing. The ratio of first to second degree infections, however, shows a marked change from 1:7·7 in the unspent fish to 1:1·8 in the kelts. This increase in the proportion of first degree infection may mean that the kelts are dying from another cause while in a carrier state and the second degree infection in kelts may be due to an increase in the number of organisms in a kelt after death.

It is not easy to answer these questions as there is no reliable method of gauging the time interval between death and autopsy. It can, however, be done in an arbitrary fashion using gill colour. All the kelts with red or pink gills were classified as newly-dead while all others were classified as long-dead. Table 6 shows that just over half of the newly-dead fish had a second degree infection and these fish doubtless died from furunculosis. In the long-dead fish over a quarter were suffering from a first degree infection which possibly means that their deaths were not entirely due to furunculosis. The fact that some newly-dead fish show second degree infection and that some long-dead fish show a first degree infection possibly indicates that more than one factor is implicated in the deaths of kelts. Some obviously die from furunculosis while others die from other causes but are carriers of the disease. They are, however, all potential sources of infection in a river and for that reason they should be removed.

To illustrate the variation in second degree infections, sections of the liver from seven fish were examined and the number of micro-colonies present was found to vary from 1 to 148 per 1 cm^2 of tissue. The size of these micro-colonies varied from 0·0098 mm. × 0·0098 mm. to 0·196 mm. × 0·147 mm. Assuming the dimensions of the organism to be 0·002 mm. × 0·001 mm. the area of the organism would be 0·000002 mm^2. From this it is possible to estimate the number of organisms in one square centimetre of tissue 5μ thick and this calculation, made for the seven fish examined, indicated that the numbers present lay between 4,000 and 110,000.

VIABILITY IN WATER

The results of previous viability experiments are summarised in Table 7, where it can be seen that the early workers were not able to detect *B. salmonicida* after about 5 days. Rushton (1933b) and Slack (1937) both detected it after a long period in tindalised mud or silt and Duff, MacArthur and Thompson (1940) could detect it in sewage. The latter workers' success may well have been due to the fact that they used a selective medium containing rabbit blood and maltose and that they employed larger volumes

TABLE 7

RESULTS OF EARLIER EXPERIMENTS ON THE VIABILITY OF *B. salmonicida*

Author	Inoculum	Medium	Vol. of medium (ml.)	Period of viability
Arkwright (1912)	Agar slope culture	Sterile tap water	100	5 days
Plehn (1924)		Pure water		2 days
		Filtered sewage		3 days
Horne (1928)	0·1 cc. broth culture	Tap water	100	3-4 days
	,,	Distilled water	100	14 or <14 days
	,,	Sewage	100	2 days
Williamson (1928)	Agar slope culture	Distilled water	15	4 days
	,,	Tap water	15	2-3 days
	,,	Natural water	15	2 days
	,,	Sterile distilled water	50	5 days
	,,	Sterile tap water	50	2-3 days
	,,	Sterile natural water	50	4-5 days
	,,	River water	15	1 day
	,,	Drain water	15	0 days
	,,	Sterile river water	15	4-5 days
	,,	Sterile drain water	15	3 days
Rushton (1933b)		'Partially sterilised' mud		6 months
Slack (1937)	4-day culture	Fresh silt suspension		<7 days
	,,	Tindalised silt		13 weeks
	,,	River water		12 weeks
Duff, MacArthur and Thompson (1940)	24-hr agar slope culture	Undiluted fresh sewage	2000	15 days
	,,	Sewage held at 56°C for 2 hrs.	2000	23 days
	,,	Beckefeld filtered sewage	2000	13 days
	,,	Autoclaved sewage	2000	22 days
	,,	Tap water	2000	11 days
	,,	Ether-treated sewage	2000	67 days

TABLE 8

RESULTS OF EXPERIMENTS ON THE VIABILITY OF *B. salmonicida* IN RUNNING WATER

Experiment No.	Inoculum (organisms-ml.)	Av. Temp. (°C)	Medium	Days viable
1	4×10^5	16·1	Yeastrel agar	8
2	1×10^6	14·9	,, ,,	7
3	4×10^6	13·5	,, ,,	8
4	4×10^5	13·3	,, ,,	12
5	1×10^5	7·9	Modified D.C.A.	19
6	$1 \times 10^{5\cdot5}$	8·4	,, ,,	17
7 pool	1×10^5	10·5	,, ,,	15
mound	9×10^5	10·5	,, ,,	16
8 pool	$2 \times 10^{5\cdot5}$	12·6	,, ,,	16
mound	$1 \times 10^{5\cdot5}$	12·6	,, ,,	12
9 pool	1×10^5	12·2	,, ,,	18
mound	1×10^5	12·2	,, ,,	11

of suspending fluid and larger samples. They do point out, however, that their results may not be applicable under field conditions.

In order to try to study the viability of *B. salmonicida* in running water under stream conditions a six foot perspex tank was constructed and the bottom was covered with stones in such a way as to form a pool (Stuart, 1953). The inoculum was introduced into the pool. Initial experiments using yeastrel agar as plating medium showed that the organism was apparently able to survive for 7-12 days depending on the initial inoculum (Table 8). As yeastrel agar is not a selective medium it was difficult to decide when the *B. salmonicida* was actually absent so a selective medium was sought. Duff, MacArthur and Thompson (1940) employed a selective rabbit blood, maltose medium but sterile rabbit blood is difficult to obtain so after some trials it was decided to use a desoxycholate citrate agar in which the lactose had been replaced by mannitol. This medium was incubated at room temperature for 4 days. On this, colonies of *B. salmonicida* are pink and can be distinguished from most of the other organisms which grow in this medium. It was also decided to employ the method of Miles and Misra (1938) for the counts in order to have surface counts and more plates for each dilution. It can be seen from Table 8 that the five experiments carried out in this manner showed that *B. salmonicida* could still be isolated from 15-19 days after inoculation. In experiments 7 and 8, the pink colonies were subcultured each day and were shown in fact to be *B. salmonicida.* In experiments 7, 8 and 9, an inoculum was placed on the mound of stones forming the downstream wall of the pool in addition to that in the pool to see if there was any difference in the persistence of the organism at the two sites. Stuart (1953) showed that the current was much stronger through the stones forming the mound than it was through the pool so that the difference in persistence of 4-7 days (Table 8) was to be expected.

These experiments show that *B. salmonicida* can remain viable in water for a much longer time than was first thought although it is still not a long time. Further, there was no mud in the experimental tank. This may be important because Rushton (1932) states that *B. salmonicida* remains both viable and virulent in partially sterilised mud for six months and Slack (1937) was able to isolate the organism from river water after 12 weeks and from sterilised silt after 13 weeks.

The average temperature of the water during each experiment was also recorded (Table 8) but there does not seem to be any direct relationship between temperature and period of viability.

The salient points which arise from these experiments are that the organism can remain viable in running water for up to 19 days and that it is more likely to persist in the quieter parts of the stream, where the salmon tend to lie.

DISCUSSION

The observations reported in this paper strongly suggest that furunculosis occurs regularly in male salmon kelts and, though the full investigation of this problem is still in its early stages, some of the outstanding points merit a brief discussion. The main problems arising at this stage would appear to be

a) the relationship of furunculosis in kelts to the disease in unspawned fish
b) the part played by furunculosis in causing the death of male kelts and
c) the importance of kelts suffering from furunculosis as sources of infection.

Furunculosis is usually considered to be a disease which is likely to become serious during the summer and it is typically associated with low water levels, which confine the upstream-migrating fish to a limited number of pools, and with high water temperatures. The present observations indicate that it may also be present when water levels are not unusually low and when water temperatures are lower than they ever are during the summer. This investigation has also revealed other differences between the summer and the autumn (or early winter) outbreaks of this disease. In the former, more females than males die from furunculosis, whereas in the latter, the death rate in males is much higher than in females. Again, external symptoms of the disease are much more common in the summer than they are in the autumn. This is, perhaps, rather a surprising result because studies of river infections have shown these to be of two types, an acute form of the disease usually unaccompanied by external symptoms and a chronic form usually marked by external symptoms. On general grounds, fish suffering from furunculosis in the winter would have been thought likely to conform with the chronic rather than with the acute form of the disease, yet the reverse appears to be the case.

It would be unwise to speculate too widely on these findings because even a cursory analysis reveals the existence of many unknown quantities. For example, it is difficult to assess the difference in the incidence of the disease between the sexes at different times of the year until more is known of the sex ratio of the river stock through the season and further consideration of the presence or absence of symptoms should await proof that furunculosis during the summer is actually the same disease and not different forms produced by different strains of the causative organism. Here it is perhaps worth remembering that comparatively little is known about the symptoms of diseases caused by bacteria in poikilothermic animals and the considerable differences which may occur in the body temperature of such forms may produce differences in symptom characteristics which do not occur in stenotherms.

As has been mentioned already, the death of male kelts after spawning has been known for a very long time, but no systematic investigations have been made of the causes of this mortality. The possibility that death may be due—at least in part—to infection with furunculosis is intriguing, but it is one which has wider repercussions. In their Final Report, the Furunculosis Committee state that furunculosis 'was probably introduced into Great Britain in trout imported from the Continent, disseminated among fish farms by the transfer of infected trout and thence was spread into rivers and streams', but if furunculosis has always been an important factor in the death of kelts, this must mean that this disease has been established in Britain for a long period and is not a comparatively recent introduction.

As it is now clear that, at least in some rivers, some or most of the male kelts which die are suffering from furunculosis, their importance as sources of infection should be borne in mind. As has been mentioned earlier, the early workers thought that *B. salmonicida* remained viable in water for only a limited period, but it is now known that it can remain viable for much longer periods e.g. for as long as 3 or 6 months under certain conditions. So far as is known, most of the kelts die soon after spawning but it is also known that salmon enter fresh water through the winter, perhaps in some numbers, so that the possibility of direct infection from adult to adult would seem to exist. Infection of the younger freshwater stages of salmon is also a possibility. In this connection it is of interest to record that, in one river, a smolt was found to be suffering from furunculosis in early April and a female kelt, which proved to be suffering from furunculosis was taken from the same river 15 days later. In a second river where a number of dead kelts had been shown to be suffering from furunculosis, one smolt died from furunculosis. Sixty one other smolts from this river were then examined and, of these, 3 were found to be infected. Recent investigations (unpublished) have shown that the viability of *B. salmonicida* in sea water is not negligible, so that its survival in the tissues of a host adapted to sea water seems a distinct possibility. Therefore, *B. salmonicida* may not only pass from one adult host to another, it may also pass from an adult host to a juvenile host and survive a period in the sea, with the consequence that at least part of the returning migrants are infected before they reach fresh water.

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SUMMARY

1. Examinations of dead kelts during the winters 1958-59, 1959-60 and 1960-61 showed that many were infected with furunculosis though kelts suffering from this disease were apparently much less likely to develop external symptoms than unspent fish.
2. The proportion of fish infected varied. In 1958-59 and 1960-61 it was high, but it was much lower during the winter of 1959-60. Water temperatures did not vary greatly over the three periods, but there may be a correlation between the amount of rainfall and the incidence of the disease.

3. It would seem that male kelts are more susceptible to furunculosis than unspent males but the cause of any differences in susceptibility between the sexes has not yet been discovered.
4. The degree of infection varied widely and three arbitrary gradings are suggested. Unspent fish mainly exhibit second and third degree infections but kelts only show first and second degree infections.
5. The viability of *B. salmonicida* was studied under conditions similar to those of a stream bed and the organism was found to remain viable from 7-19 days.
6. Some of the general implications of this survey are briefly discussed.

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